

Determination Of Natural Radionuclide Concentration in Soil Samples Within Federal College of Education (Technical) Gusau, Zamfara State

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ABSTRACT

The Earth's environment naturally contains radioactive elements, including long-lived isotopes such as 40K, 232Th, and 238U. Excessive exposure to these elements can pose health risks to humans, animals, and plants. This research aimed to identify and quantify these radionuclides in soil samples collected from various locations within the Federal College of Education (Technical) Gusau, Zamfara State. Specifically, we focused on the School Academic Area (SAA), School Administrative Area (SADA), School Farm Area (SFMA), Students Hostel Area (SSHA), and Staff Quarters Area (SSQA). The detected radionuclide levels were compared to global acceptable limits established by the IAEA and UNSCEAR. Using a Na (TI) detector, we examined the activity content of these elements in the soil samples. The mean average specific activities for 40K, 226Ra, and 232Th were determined to be (390.0861 ± 6.0420) Bq/kg, (22.6847 ± 2.337) Bq/kg, and (30.2855 ± 3.4990) Bq/kg, respectively. Comparison of these values with worldwide averages (40K=412 Bq/kg, 226Ra=35 Bq/kg, and 232Th=45 Bq/kg) established by the IAEA, UNSCEAR, and ICRP, as well as other global studies, indicates that both students and staff at the Federal College of Education Technical Gusau, Zamfara State, are safe from radiation hazards and can continue their studies and work without concern.

Keywords: NORMs, 40K, 232Th, 238U, Soil, Radionuclides

1.0 INTRODUCTION

Radiation and its potential health Hazard to humans is a major concern throughout the world, as it is an inevitable part of environmental materials such as soil, air and water (Khan *et al.*, 2022). The earth is radioactive as a result of natural sources as well as human activities in the environment, these activities involves bombardments of the environments by man with these (radionuclides) ionization radiation IAEA 2022. Radiation from the sun, cosmic rays, and naturally occurring radioactive materials (NORMs) present in the earth's crust are the main sources of radiation exposure for humans, it is a well-known fact that traces of radionuclides are present in air, water and soil, and human body inhales and ingest radionuclide in everyday life which is why radioactivity measurement has been ubiquitous on the earth crust (Moses and Mukhtar, 2019; Tarbool, *et al.*, 2022 and Idris, *et al.*, 2024).

Additionally, numerous human activities significantly contribute to increased radiation exposure, such activities include. Nuclear reactors and nuclear bomb testing, Coal power plants, improper agricultural practices and radiation medical facilities, all these produces radionuclide which are often refers to as technological enhance naturally occurring radioactive materials

(TENORMs). Some of the radionuclides are Potassium (K), Thorium (Th), Uranium (U) and their decay series which are radium and radon which have been in existence since the formation of the earth (Moses and Mukhtar, 2019; Tarbool *et al.*, 2022; Godwin *et al.*, 2022 and Nafisa, *et al.*, 2022). Geographical and geological factors primarily determine the presence of naturally occurring radioactive materials (NORMs), which are often found in soil in every region of the world at various quantities, and the external exposure to gamma radiation they are associated with. However, NORMs are only found at trace levels, or around 10 parts per million by mass, which is about half of the radiation dosage that humans in surroundings experience (Tadesse, 2022).

The level of radiation in any region is largely influenced by the local geological conditions, with igneous rocks exhibiting higher radiation levels, including granites and gneisses. These geological activities primarily take place near the Federal College of Education (Technical) in Gusau, Zamfara State, specifically in a small community called Kotorkoshi, located just a few meters from the institution. It is crucial to measure the radioactivity in this environment, as noted by (Akpanowo *et al.*, 2020), indicating that 87% of the radiation doses encountered by individuals come from naturally

occurring radioactive isotopes such as uranium, thorium, and potassium, along with their decay products. This is why this present study will accurately take the radioactivity measurements of soil samples within Federal College of Education (Technical) Gusau, Zamfara states as well as to quantify the amount of Uranium, Thorium and Potassium that are present in the soil samples so as to ascertain lower and elevated area of radiation exposure to the students and staff.

Similar to Table 1 which shows the methods and technologies used by various researchers in Nigeria to study and determine the levels of radioactivity and radioactive elements in the collected soil samples, this study used the NaI(TI) detector method to study NORMs in soil samples taken from twenty (20) points in five (5) different locations within Federal College of Education (Technical) Gusau, Zamfara State.

Table 1: Shows Different method of NORMs Analysis

S/No.	Author	State	Method of Analysis
1.	Ademola et al (2014).	Osun	Gamma Spectroscopy
2.	Itado et al (2020)	Kogi	HpGe Detector
3.	Laniyan and Adewumi (2021)	Taraba	HPLC-ICPMS
4.	Jushua (2021)	Oyo	Na(TI) Detector
5.	Echeweozo and Okeke (2021)	Abia	Na(TI) Detector

2.0 MATERIALS AND METHODS

2.1 Sample Area

Figures 2.1 and 2.2 below show the maps of Gusau Local Government Area (LGA) and Federal College of Education Technical Gusau, respectively. The college is situated within Gusau LGA at approximately 12.150°N latitude and 6.720°E longitude in northwest Nigeria. It is bordered by Jauri Area (12.150°N, 6.730°E) to the northeast, Damba Area (12.130°N, 6.730°E) to the southeast, Geba and Zamfarawa villages (12.140°N, 6.720°E) to the southwest and Marerin Fulani Area to the northwest.

2.2 Topography: The Federal College of Education Technical Gusau is situated within the extensive floodplains of an inland river valley system in Gusau Local Government Area. The floodplain elevation in this region is approximately 150 meters above sea level. The alluvial deposits within these floodplains exhibit a wide range of grain sizes, from gravel to clay. During the rainy

season, these sediments become saturated, storing significant amounts of water that can be utilized during the dry season. Underlying these substantial sedimentary deposits, the Precambrian Basement Complex, as described by (Abbasi *et al.*, 2020), forms the bedrock of the region.

2.3 Samples collection

Twenty soil samples were collected from five distinct locations within the institution's environment. At each location, samples were extracted from a depth of 15-20 cm below the surface to minimize contamination from atmospheric fallout. The sampling sites were labeled as follows: School Academic Area, School Administrative Area, School Farming Area, Students Hostel Area, and Staff Quarters Area. These locations were geo-referenced using a Global Positioning System (GPS) and subsequently mapped using Geographic Information System (GIS) software, as illustrated in Table 2 and Figures 1 and 2.

Table 2 Showing samples location and their coordinates in the study Area.

S/No.	Sample ID	Name of sample area	Coordinates	
			North	East
1.	SAA1	School Academic Area 1	12 ⁰ 08'340"	006 ⁰ 43'0.7"
2.	SAA2	School Academic Area 2	12 ⁰ 08'55.8"	006 ⁰ 43'35.0"
3.	SAA3	School Academic Area 3	12 ⁰ 08'52.2"	006 ⁰ 43'27.3"
4.	SAA4	School Academic Area 4	12 ⁰ 08'48.6"	006 ⁰ 43'19.3"
5.	SADA1	School Administrative Area 1	12 ⁰ 08'79.9"	006 ⁰ 43'72.9"
6.	SADA2	School Administrative Area 2	12 ⁰ 08'77.3"	006 ⁰ 43'25.1"
7.	SADA3	School Administrative Area 3	12 ⁰ 08'75.0"	006 ⁰ 43'28.4"
8.	SADA4	School Administrative Area 4	12 ⁰ 08'77.1"	006 ⁰ 43'32.1"

9.	SFMA1	School farming Area 1	12 ⁰⁰ 8'34.0"	006 ⁰³ 3'0.7"
10.	SFMA2	School farming Area 2	12 ⁰⁰ 8'22.8"	006 ⁰⁴ 2'06.3"
11.	SFMA3	School farming Area 3	12 ⁰⁰ 8'28.8"	006 ⁰⁴ 3'34.5"
12.	SFMA4	School farming Area 4	12 ⁰⁰ 8'39.3"	006 ⁰⁴ 3'48.4"
13.	SSHA1	Students hostel Area 1	12 ⁰⁰ 8'59.8"	006 ⁰⁴ 3'48.0"
14.	SSHA2	Students hostel Area 2	12 ⁰⁰ 8'59.5"	006 ⁰⁴ 3'51.1"
15.	SSHA3	Students hostel Area 3	12 ⁰⁰ 8'522.0"	006 ⁰⁴ 3'48.1"
16.	SSHA4	Students hostel Area 4	12 ⁰⁰ 8'60.0"	006 ⁰⁴ 3'44.5"
17.	SSQA1	Staff quarters Area 1	12 ⁰⁰ 8'71.8"	006 ⁰⁴ 3'11.1"
18.	SSQA2	Staff quarters Area 2	12 ⁰⁰ 8'79.2"	006 ⁰⁴ 3'11.5"
19.	SSQA3	Staff quarters Area 3	12 ⁰⁰ 8'81.0"	006 ⁰⁴ 3'16.0"
20.	SSQA4	Staff quarters Area 4	12 ⁰⁰ 8'70.1"	006 ⁰⁴ 3'19.1"

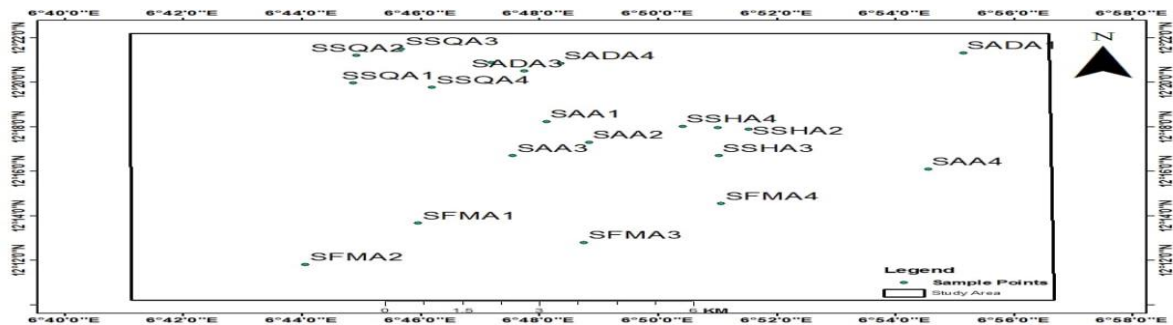


Figure1. Shows sample points of the study Area

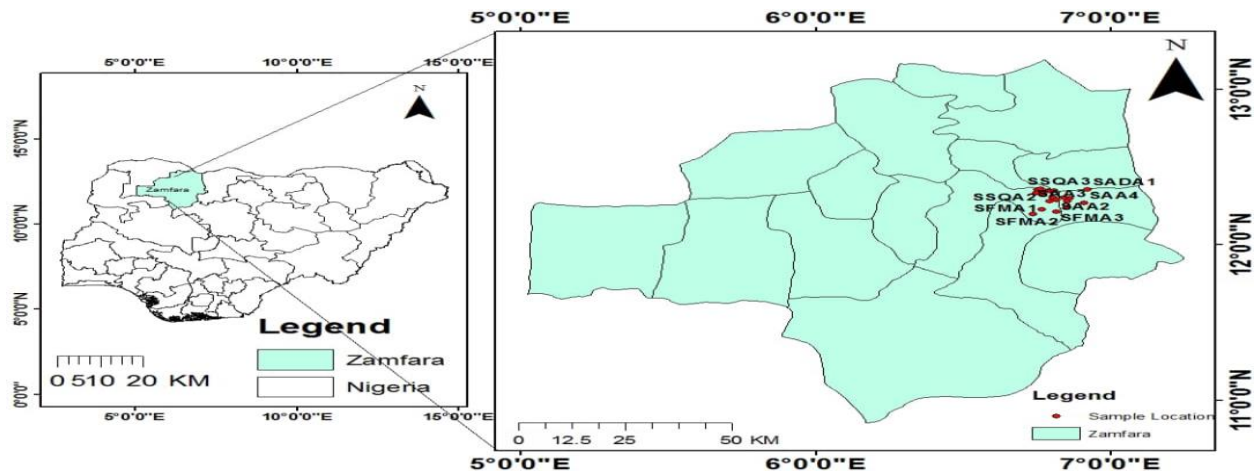


Figure 2. Showing the Map of the study Area

2.4 Samples Preparation

The collected soil samples were oven-dried at 60°C for 24 hours to remove residual moisture. Subsequently, the dried samples were pulverized into a fine powder and packaged into radon-impermeable cylindrical plastic containers, sized to fit the detector vessel (7.6 cm x 7.6 cm). To ensure airtight containment, the containers were triple-sealed using a combination of Vaseline jelly, candle wax, and masking tape. After a 30-day storage period to achieve secular radioactive equilibrium, the samples were subjected to gamma spectroscopy analysis.

2.5 Samples Evaluation and Analysis

A photomultiplier tube (PMT) optically linked to a 76x76mm NaI (TI) detector crystal was used for the analysis. The assembly has an internal preamplifier and an external source with a voltage of one kilovolt. A lead shield of 6 cm and made of copper and cadmium sheets encloses the detector. The goal of this configuration is to reduce the impact of background and dispersed radiation. Canberra Nuclear Products' Maestro is the data acquisition program. For every sample, the

measurements were taken over a duration of 29000 seconds. The following equation was used to calculate the activity concentrations in each sample based on the peak area of each energy in the spectrum:

Specific activity

The specific activity (A) in soil samples of the present study can be evaluated using equation (1)

$$C(Bq.kg^{-1}) = \frac{C_n}{C_{fk}} \quad (1)$$

Where,

C = activity concentration of the radionuclide in the sample given in BqKg⁻¹

C_n = count rate (counts per second)

Count per second (cps) = Net Count / (5 + Live Time)

C_{fk} = Calibration factor of the detecting system.

Two calibration point sources, Cs-137 and Co-60, were used to calibrate the system for energy and efficiency. These were counted for 30 minutes using an amplifier gain that provides 72% energy resolution for the 66.16 keV of Cs-137. IAEA gamma Spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak) and RTG-1 for Th-232 (Ti-208) were the standard used in checking the Calibration and the background count rate was done for 29000 seconds just as those of the samples.

3.0 DATA ANALYSIS AND RESULTS**Table 3: Shows Concentration Activity for 40K, 238U and 232Th**

S/No.	Sample ID	K-40 (Bq/Kg)	Error ± (Bq/Kg)	Ra-226 (Bq/Kg)	Error ± (Bq/Kg)	Th-232 (Bq/Kg)	Error ± (Bq/Kg)
1.	SAA1	307.9316	8.2426	20.8526	2.3170	27.8221	2.6226
2.	SAA2	357.6983	8.5537	21.6640	1.9694	17.3318	2.5086
3.	SAA3	488.3359	9.7978	19.3466	3.8230	14.5952	1.7104
4.	SAA4	289.8911	3.2659	21.4319	1.8536	37.1722	4.9031
5.	SADA1	326.4386	2.0218	22.4745	1.5060	31.3569	7.6283
6.	SADA2	414.9300	7.4650	23.3086	1.7377	40.5929	3.2360
7.	SADA3	485.6921	8.7092	21.2002	2.8962	35.8030	3.5348
8.	SADA4	516.9518	6.3764	16.5663	2.5487	38.1984	2.7366
9.	SFMA1	323.8569	2.0220	18.6747	2.0853	40.5245	6.4994
10.	SFMA2	224.1213	4.6656	33.9435	1.5060	47.8905	3.9909
11.	SFMA3	311.3530	3.7325	17.8406	1.3902	32.8392	3.5346
12.	SFMA4	262.6750	5.7543	19.4741	2.8962	18.3580	1.2543
13.	SSHA1	429.0824	6.6874	27.3401	2.0042	25.8837	1.9042
14.	SSHA2	544.7900	5.7543	24.3049	1.6219	15.0513	1.7446
15.	SSHA3	488.1804	7.7761	20.9685	2.3170	37.1722	2.7366
16.	SSHA4	307.7760	6.6874	21.4666	2.8962	37.1722	2.1665
17.	SSQA1	425.0389	5.4432	23.2159	3.4754	19.7263	2.6579
18.	SSQA2	491.9129	4.3546	28.9620	2.4328	39.5667	3.3067
19.	SSQA3	391.2908	6.3764	18.7674	1.6219	16.8757	2.8164
20.	SSQA4	431.2597	7.1540	32.0899	1.7377	25.8837	3.0445

Table 3.1 Represent Activity Concentration of Samples Location 1 (School Academic Area)

Sample Identity (SAA)	Bq/Kq	Error ±
K - 40	360.9642	7.465
Ra - 226	20.8237	2.4907
Th- 232	24.2303	2.9361

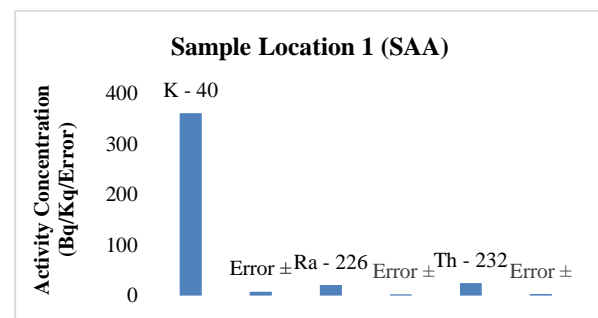


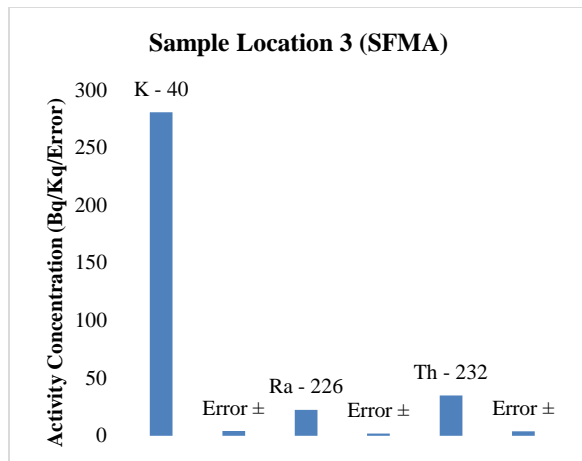
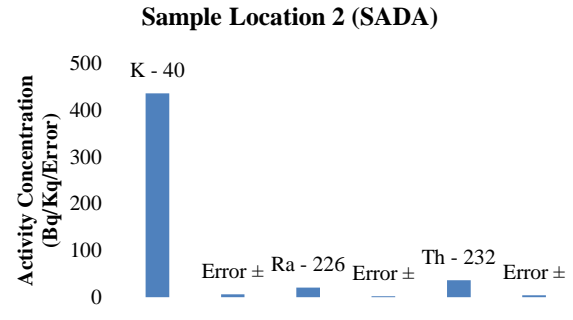
Figure 3.1 Shows the Chart of (K- 40, Ra- 226 & Th - 232) Activity Concentration in Sample Location 1 School Academic Area (SSA)

Table 3.2 Represent Activity Concentration of Sample Location 2 School Administrative Area

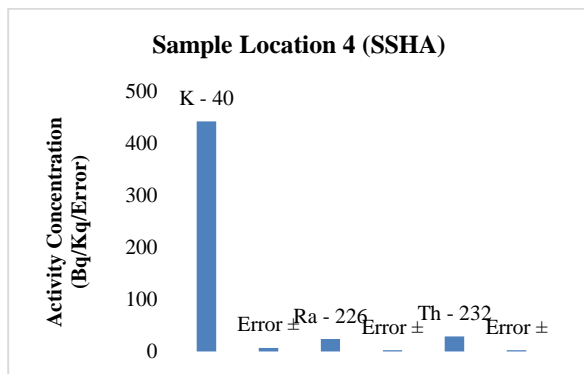
Sample Identity (SADA)	Bq/Kq	Error \pm
K - 40	436.003	6.1431
Ra - 226	20.8874	2.1721
Th- 232	36.4878	4.2839

Table 3.3 Represent Activity Concentration of Sample Location 3, School farming Area

Sample Identity (SFMA)	Bq/Kq	Error \pm
K - 40	280.5016	4.0436
Ra - 226	22.4832	1.9694
Th- 232	34.9030	3.8198

**Figure 3.3 Shows Chart of (K- 40, Ra- 226 & Th - 232) Activity Concentration in Sample Location 3 School farming Area (SFMA)****Figure 3.2 Shows the Chart of (K- 40, Ra- 226 & Th - 232) Activity Concentration in Sample Location 2 School Administrative Area (SADA)****Table 3.4 Represent Activity Concentration of Sample Location 4 School Students hostel Area**

Sample Identity (SSHA)	Bq/Kq	Error \pm
K - 40	442.4572	6.7263
Ra - 226	23.52003	2.209825
Th- 232	28.81985	2.137975

**Figure 3.4 Shows the Chart of (K- 40, Ra- 226 & Th - 232) Activity Concentration in Sample Location 4 Students hostel Area (SSHA)****Table 3.5 Represent Activity Concentration of Sample Location 5 Staff quarters Area**

Sample Identity (SSQA)	Bq/Kq	Error \pm
K - 40	434.8756	5.8320
Ra - 226	25.7588	2.3169
Th- 232	25.5131	2.9563

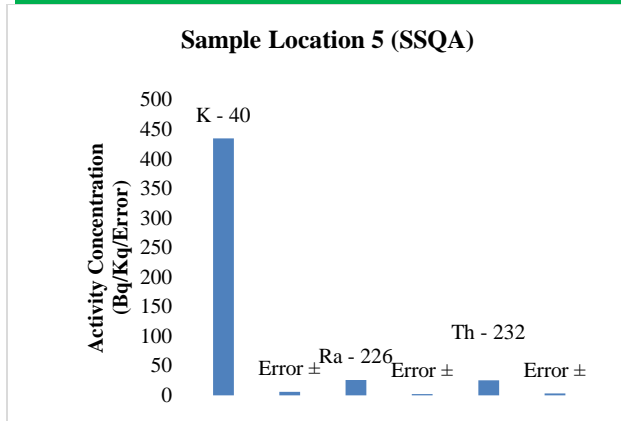


Figure 3.5 Shows the Chart of (K- 40, Ra- 226 & Th - 232) Activity Concentration in Sample Location 5 Staff quarters Area (SSQA)

3.1 The International Atomic Energy Agency Standard (IAEA)

The world's preeminent intergovernmental platform for scientific and technological collaboration in the peaceful use of nuclear energy is the International Atomic Energy Agency (IAEA, 2022). The IAEA was founded in 1957 as a stand-alone international agency under the United Nations system. Its mission is to certify nuclear technology's peaceful usage while optimizing its contribution to society. The IAEA promotes the safe, secure, and peaceful use of nuclear energy through collaboration with its 164 Member States and several international partners Aurani and Tahtat (2001).

Table 3.6 is the standard reference material results produced by the International Atomic Energy Agency (IAEA) that can be used as minimum detection limits for the activity of the three major naturally occurring radionuclide materials in Bq/ Kq and their errors.

Table 3.6 Represent Standard of the Activity Concentration of (K- 40, Ra- 226 & Th - 232)

Elements	Bq/ Kq	Error ±
(K-40)	13900	58.95
(Ra- 226)	5095.8	60.18
(Th-232)	3050.8	39.75

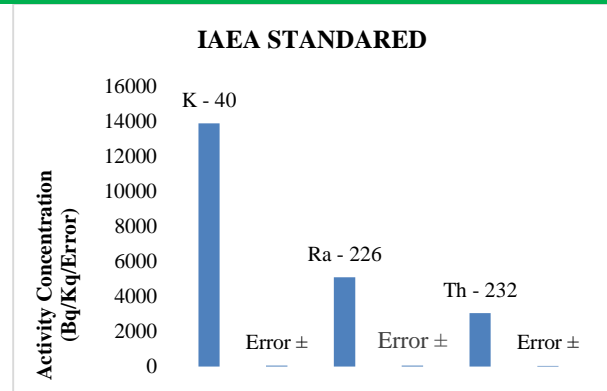


Figure 3.6 Shows the Chart of the standard activity concentration of (K- 40, Ra- 226 & Th - 232)

Figure 3.6 illustrates the activity and associated uncertainty for the standard radionuclides. Potassium-40 (K-40) exhibits the highest activity at 13,900 Bq/kg with an uncertainty of 0.004. Uranium-238 (U-238) follows with an activity of 5,095.8 Bq/kg and an uncertainty of 0.002. Thorium-232 (Th-232) has the lowest activity at 3,050.8 Bq/kg with an uncertainty of 0.00[error]. Please verify the uncertainty value for Th-232.

4.0 DISCUSSION

The present study directly utilized the specific activities of natural radionuclides, including potassium-40 (^{40}K) at 1460 keV, radium-226 (^{226}Ra) via its decay product bismuth-214 (^{214}Bi) at 1765 keV, and thorium-232 (^{232}Th) via its decay product thallium-208 (^{208}Tl) at 2614 keV. Table 3 provides a detailed list of the specific activities for each radionuclide.

The lowest specific activity of ^{40}K was observed in soil samples collected from the School Farm Area (SFMA) at 280.50 ± 4.04 Bq/kg, as depicted in Figure 3.3. Conversely, the highest specific activity of ^{40}K was found in samples from the School Students Hostel Area (SSHA) at 442.45 ± 6.72 Bq/kg, as shown in Figure 3.4. The mean average specific activity of ^{40}K across all sampled locations, as presented in Table 3, was 390.96 ± 6.03 Bq/kg, which is remarkably close to the recommended world average of 400 Bq/kg (Idris et al., 2024).

It was also found that the lowest specific activity of ^{226}Ra was (20.823 ± 2.172) Bq/kg for the soil samples collected from the School Administrative Area (SADA) as shown in Figure 3.2, while the highest specific activity of ^{226}Ra was (25.75 ± 2.316) Bq/kg for the soil samples collected from the School Staff quarters area (SSQA) as shown in figure 3.5. The mean average of ^{226}Ra for the total number of soil samples collected in all the different location as shown in Table 3, was

(22.684 ± 2.427 Bq/kg). While It was found that the lowest specific activity of ^{232}Th was (24.230 ± 2.936 Bq/kg) for the soil samples collected from the School Academic Area (SAA) as shown in Figure 3.1, and then the highest specific activity of ^{232}Th was (36.903 ± 4.283 Bq/kg) for the soil samples collected from the School Administrative area (SADA) as shown in figure 3.2. The mean average of ^{232}Th for the total number of soil samples collected in all the different location as shown in table 3, was (30.285 ± 3.499 Bq/kg).

From the table 3, the three radionuclide detected (^{40}K , ^{226}Ra and ^{208}Th), both ^{226}Ra and ^{208}Th radionuclide belong to the natural radioactivity decay series with

world average that is equal to (35 and 45) Bq/kg respectively, the mean average of ^{226}Ra and ^{232}Th for the total number of soil samples collected in all the different location in the present study are (22.684 ± 2.427 Bq/kg). and (30.285 ± 3.499 Bq/kg) respectively and it was found to be lower than the recommended world average of (35 and 45) Bq/kg respectively given by UNSCEAR. For ^{40}K radionuclide, the mean average for the total number of soil samples collected in all the different location in this present work was (390.96 ± 6.03 Bq/kg) and it was found to be lower than the recommended world average of (412 Bq/kg) but almost similar to recommended world average in Bq/kg.

Table 4. Shows comparison of activity concentration levels in different area of the world with the present study.

S/N	Country	^{40}K Average specific Activity in Bq/kg	^{226}Ra Average specific Activity in Bq/kg	^{232}Th Average specific Activity in Bq/kg	
1.	Turkey	342	310	37	Karahan and Balyukan 2000
2.	Al-Najaf (Iraq)	201.47	10.17	5.91	Tarbool et al., 2022
3.	Delta (Nigeria)	1586.82	27.26	37.67	Ezekiel and Esi, 2023
4.	China	75.78	8.69	3.30	Yan Shi et al., 2023
5.	Nasarawa (Nigeria)	277.62	5.66	0.90	Idris et al., 2024
6.	Bangladesh	494.2	63.6	103.4	Ahosan et al., 2018
7.	Present study	290.96	22.68	30.28	Habib

5.0 CONCLUSION

The analysis of soil samples collected from various locations within the Federal College of Education Technical Gusau, Zamfara State, revealed the presence of naturally occurring radionuclides, namely potassium-40 (^{40}K), radium-226 (^{226}Ra), and thorium-232 (^{232}Th). The measured activity concentrations of these radionuclides were found to be below the recommended world average limits. Gamma spectroscopic analysis conducted at the Center for Energy Research and Training, Ahmadu Bello University Zaria, confirms that the soil samples pose negligible radiation risk to students and staff, allowing them to carry out their daily activities without concern.

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